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RESEARCH MEMORANDUM

INVESTIGATION OF AN UNDERSLUNG NORMAL-WEDGE INLET AT FREE-STREAM MACH NUMBERS FROM 1.50 TO 1.9[illegible]

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Cleveland, Ohio

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

INVESTIGATION OF AN UNDERSLUNG NORMAL-WEDGE INLET AT FREE-STREAM MACH NUMBERS FROM 1.50 TO 1.99

By Donald J. Vargo and Maynard I. Weinstein

SUMMARY

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The performance of a normal-wedge inlet with a straight and a sweptback splitter plate was investigated and is compared with a previously tested scoop-type inlet. Both the normal-wedge and the scoop-type inlets were tested on a one-fifth scale model of a supersonic missile forebody in the Lewis 8- by 6-foot supersonic wind tunnel.

In general, no significant differences could be detected between the performances of the normal-wedge configurations with straight and sweptback splitter plates. At the higher Mach numbers both of the normal-wedge inlets had higher pressure recoveries and greater stability, but higher drag than the scoop inlet. On a thrust-minus-drag basis the higher recovery made the normal-wedge inlets superior at a free-stream Mach number of 1.99, while the equal or better recoveries of the scoop inlet made it better at free-stream Mach numbers of 1.80 and 1.50.

Author

INTRODUCTION

Previous investigations of scoop-type inlets (refs. 2 to 5) have shown serious starting problems and small ranges of stable subcritical flow. Because these difficulties were anticipated for the particular missile forebody scoop-inlet configuration of reference 1, an alternate normal-wedge inlet adaptable to the internal and external geometry of the missile forebody was designed and tested with both a straight and a sweptback splitter plate.

The experimental normal-wedge-inlet performance and an over-all thrust-minus-drag comparison between the scoop-type and the normal-wedge inlets are presented in this report. The investigation was conducted in the Lewis 8- by 6-foot supersonic wind tunnel over a range of mass flows at angles of attack of -3° to 10° and free-stream Mach numbers of 1.50, 1.80, and 1.99.

SYMBOLS

A	area, sq ft
C_D	drag coefficient
D	full-scale forebody drag, lb
D_b	full-scale bypass drag, lb
F_n	net thrust (jet thrust minus free-stream momentum), lb
$\frac{F_n - D - D_b}{F_{n,i}}$	net-thrust-minus-drag ratio
$F_{n,i}$	ideal net thrust (100 percent pressure recovery), lb
h	height of inlet splitter plate from fuselage
M	Mach number
m	mass flow, slugs/sec
P	total pressure, lb/sq ft
$\frac{\Delta P}{P_2}$	total-pressure distortion, $\frac{P_{max} - P_{min}}{P_{av}}$
δ	boundary-layer thickness

Subscripts:

av	average
max	maximum
min	minimum
0	free stream
2	compressor-face measuring station

APPARATUS AND PROCEDURE

The model tested is shown schematically in figure 1 and photographically in figure 2. A normal-wedge inlet was mounted on the underside of a supersonic missile forebody; the model was sting-mounted through a system of balances in the Lewis 8- by 6-foot supersonic wind tunnel.

Inlet details and diffuser-area variation are shown in figures 3 and 4, respectively. The compression-wedge half-angle was 12°, and the cowl leading edge fell on a plane which was at an angle of 40.13° with respect to the inlet centerline. The two boundary-layer splitter plates (straight and sweptback) were set at an h/δ of slightly greater than 1. (The boundary-layer thickness δ, as determined from ref. 1, was 0.57 in. at zero angle of attack.) The sweptback splitter plate was obtained by cutting back the straight-splitter-plate configuration at an angle of 42° with respect to its leading edge. Boundary layer was removed by using a wedge-type diverter, which directed the boundary layer outward and upward. The fuselage approach surface ahead of the inlet was flattened and inclined inward at an angle of 2.2° with respect to the fuselage centerline giving an inlet Mach number of 2.025 for a free-stream Mach number of 1.99 and zero angle of attack.

The instrumentation at the diffuser exit was identical to that described in reference 1. The total pressure was obtained by an area weighting of 32 total pressures measured at the compressor face (model station 96.6). Pressure fluctuations due to unstable inlet flow were recorded by using a pressure transducer mounted in the diffuser duct floor. Mass flow was controlled by varying a plug in the diffuser exit; mass-flow calculations were made using the measured average total pressure and assuming that the flow was choked at the minimum area determined by the exit plug. The mass-flow ratio m_2/m_0 is defined as the ratio of the mass flow through the diffuser duct to the mass flowing in the free stream through an area equal to the inlet area projected on a plane normal to the approach surface.

Axial and normal forces were measured by an internally mounted strain-gage balance located forward in the model and a rear normal-force link. This rear link not only increased the accuracy of the normal-force readings but also aided in keeping model deflection due to air loads at a minimum. Forces measured by the balance system were the combined internal duct forces, fuselage forces, and base forces. The drag presented is the streamwise component of the measured forces excluding the base force and the change in momentum of the internal flow from free stream to the duct exit.

The test was conducted at free-stream Mach numbers of 1.50, 1.80, and 1.99 and angles of attack of -3°, 0°, 5°, 10° for a range of mass-flow ratios. The Reynolds number per foot of length was about 5.4×10^{6}.

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RESULTS AND DISCUSSION

The performances of the two normal-wedge configurations tested (with straight and sweptback splitter plates) are presented in figure 5. Total-pressure recovery P_2/P_0, engine-face total-pressure distortion $\Delta P/P_2$, and external drag coefficient C_D are presented as a function of the diffuser mass-flow ratio m_2/m_0. Also shown are lines of constant compressor-face Mach number M_2. In general, total-pressure recoveries, total-pressure distortions, and external drag coefficients for the two configurations were almost identical. Peak pressure recoveries of 0.825, 0.888, 0.925 were obtained at free-stream Mach numbers of 1.99, 1.80, and 1.50, respectively, at zero angle of attack. At free-stream Mach numbers of 1.99 and 1.80 distortion values of about 17 percent were obtained at critical mass flows decreasing to 15 percent at a free-stream Mach number of 1.50. These critical distortion values were independent of angle of attack except at an angle of attack of -3° and a free-stream Mach number of 1.99, where the critical distortion value increased to 28 percent (fig. 5(b)).

From pressure transducer recordings it was determined that the straight-splitter-plate normal-wedge configuration was stable over the entire mass-flow range tested. The sweptback splitter plate also was stable over the mass-flow range tested except for the minimum mass-flow point of 0.55 at a free-stream Mach number of 1.99 and an angle of attack of -3°, which was in a region of low-amplitude instability.

Minimum values of drag coefficient of 0.120, 0.124, and 0.143 were obtained at free-stream Mach numbers of 1.99, 1.80, and 1.50, respectively (fig. 5).

The effect of angle of attack was, in general, small. The presence of the body enabled both the normal-wedge and the scoop inlets of reference 1 to maintain about the same levels of critical pressure recovery and mass flow at angles of attack up to 10°. In contrast, the normal-wedge inlets of references 6 and 7 suffered considerable losses in pressure recovery at angle of attack.

Compressor-face total-pressure contours showing the effects of angle of attack, inlet mass-flow ratio, and free-stream Mach number are presented in figure 6 for the straight-splitter-plate configuration. Again no large effect of angle of attack is apparent; however, increasing model angle from 0° to 5° improves the general symmetry of the profiles. In general, decreasing the mass flow as well as the free-stream Mach number improved the general symmetry of the total-pressure contours (figs. 6(b) and (c)).

The performances of the straight-splitter-plate normal-wedge configuration and the basic scoop inlet of reference 1 can now be compared.

As previously mentioned, the peak recoveries of the straight splitter plate were 0.825, 0.888, and 0.925 at free-stream Mach numbers of 1.99, 1.80, and 1.50, while those of the basic scoop inlet (ref. 1) were 0.785, 0.875, and 0.932, respectively. From a stability standpoint the normal-wedge configuration was found to be stable over the entire Mach number
3946 and mass-flow range tested, whereas the basic scoop inlet had about 10-percent stability at a free-stream Mach number of 1.99 with the stability range increasing as free-stream Mach number was decreased.

Comparing the external drag coefficients of the two inlet installations shows that, in general, the drag coefficients of the forebody with the straight-splitter-plate normal-wedge inlet are 0.01 higher than those with the scoop-type inlet installation of reference 1.

In order to compare the straight-splitter-plate normal-wedge and the scoop inlets on the basis of a single performance parameter, a net-thrust ratio including a bypass drag $\frac{F_n - D - D_b}{F_{n,i}}$ was determined. These net-thrust computations were made by assuming a fixed inlet size and a sonic bypass discharging air parallel to the free stream. The largest value of this parameter for each inlet at each Mach number and an angle of attack of 5° is plotted in figure 7. The higher recovery of the normal-wedge inlet makes it superior at a Mach number of 2.0, while the combination of almost equal recovery plus lower drag makes the scoop inlet more favorable at Mach numbers of 1.80 and 1.50.

Performance of the scoop inlet has been improved by throat bleeding (ref. 1), and such techniques would very likely show performance gains for the normal-wedge inlet. (Refs. 8 to 11 indicate gains of 3 to 10 percent in propulsive thrust by bleeding from the inlet throat of a variety of inlets.)

SUMMARY OF RESULTS

Two underslung normal-wedge inlet configurations (with straight and sweptback splitter plates) were investigated on a missile forebody, and the results are compared with a previously tested scoop-type inlet on the basis of maximum thrust-minus-drag at free-stream Mach numbers of 1.99, 1.80, and 1.50 and at angles of attack of -3°, 0°, 5°, and 10°. For this range of variables the following results were obtained:

1. At a free-stream Mach number of 1.99, the higher recovery of the normal-wedge inlets offset the lower drag of the scoop inlet making the normal-wedge inlets superior (on a thrust-minus-drag basis). However, at free-stream Mach numbers of 1.80 and 1.50, the equal recovery plus the lower drag made the scoop inlet better than the normal-wedge configurations.

2. For the normal-wedge inlets the splitter-plate configurations had no significant effect on pressure recovery or external drag coefficient. Peak recoveries of 0.825 and minimum drag coefficients of 0.120 were obtained at a free-stream Mach number of 1.99. Both normal-wedge inlets were stable over the range of mass flows tested (down to 57 percent of critical mass-flow ratio at a free-stream Mach number of 1.99).

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics 3946
Cleveland, Ohio, September 26, 1956

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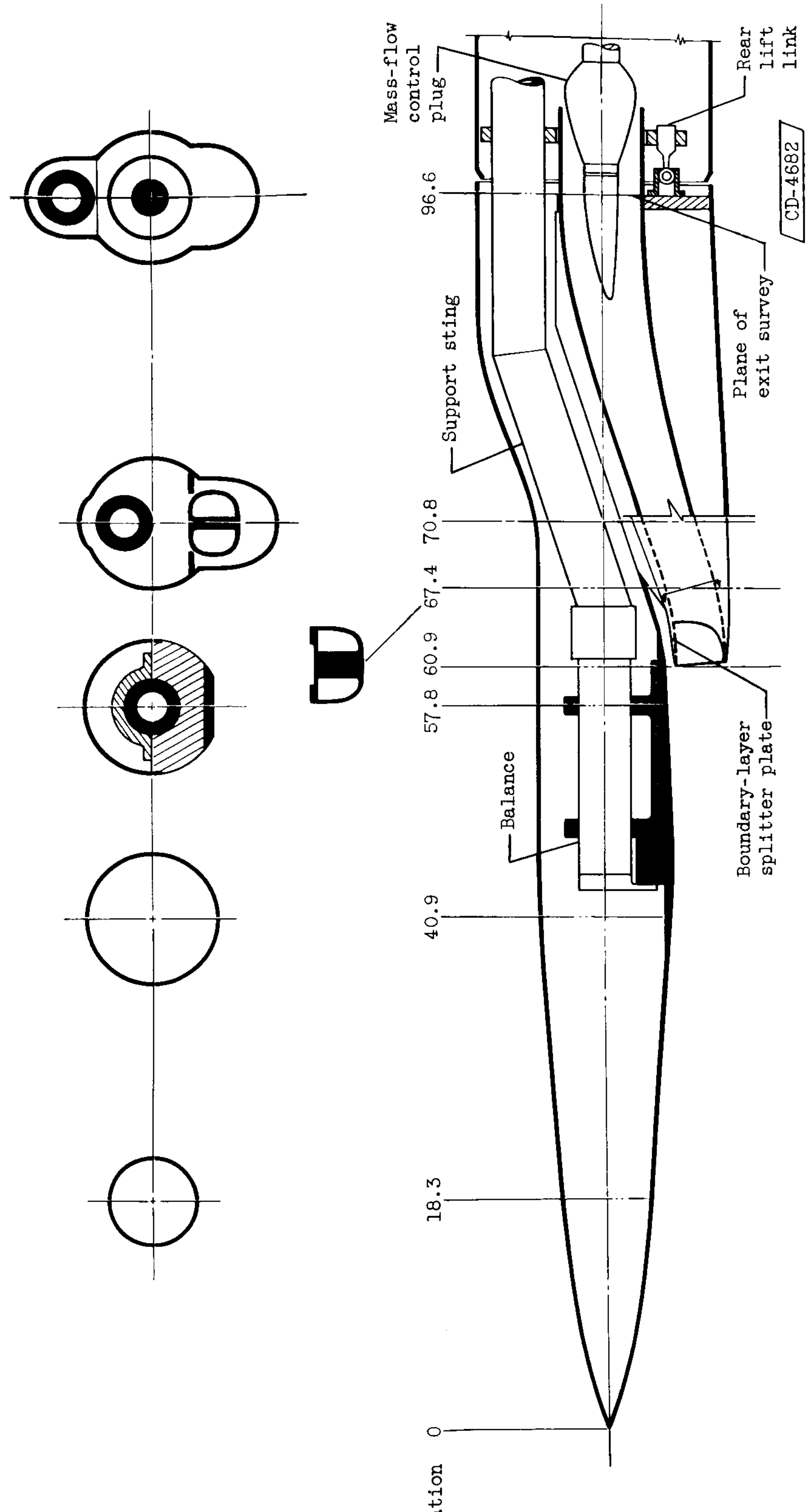

Figure 1. - Schematic drawing of model.

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Figure 2. - Model.

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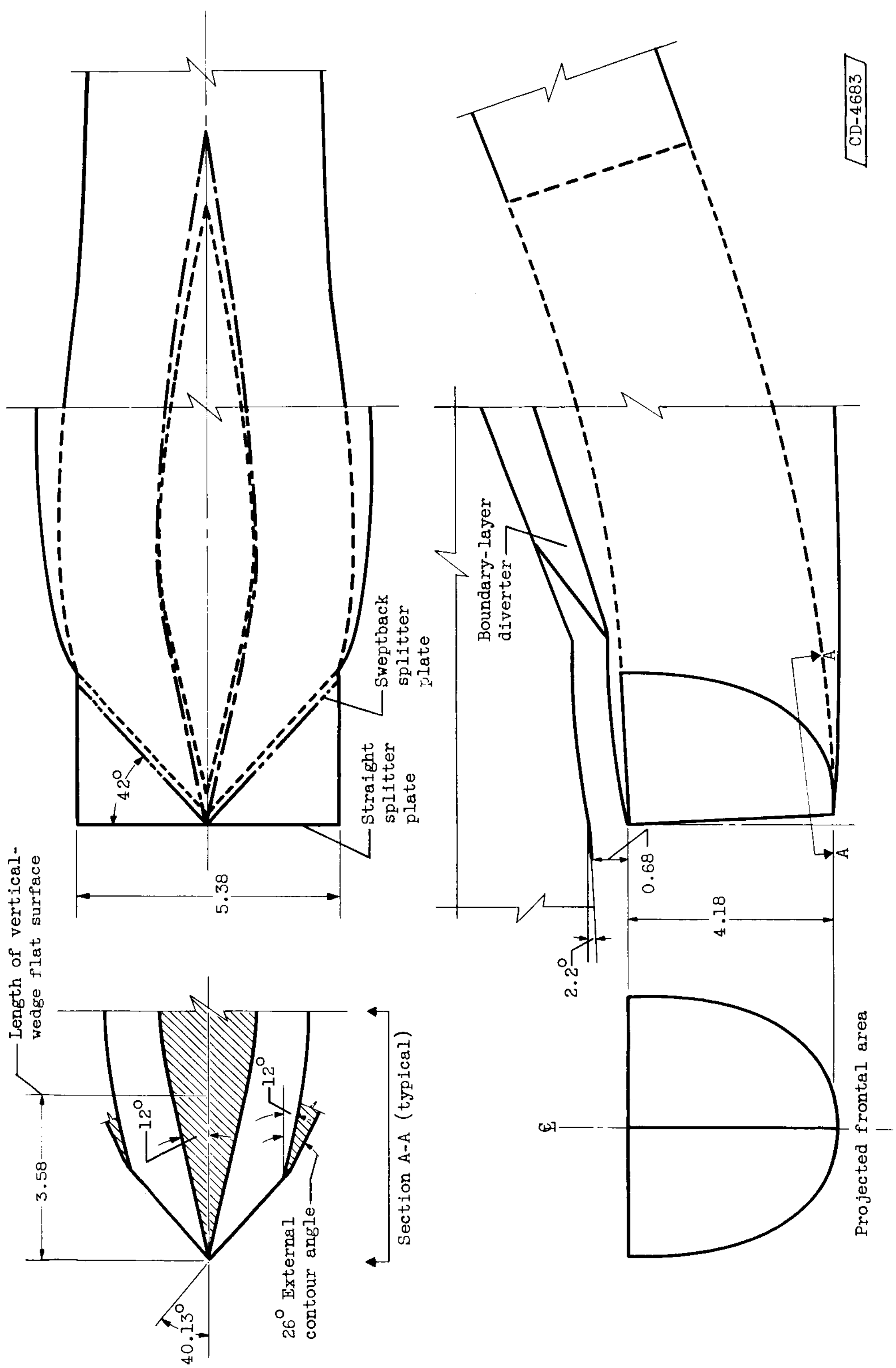

Figure 3. - Details of inlet. (All dimensions in inches except where noted.)

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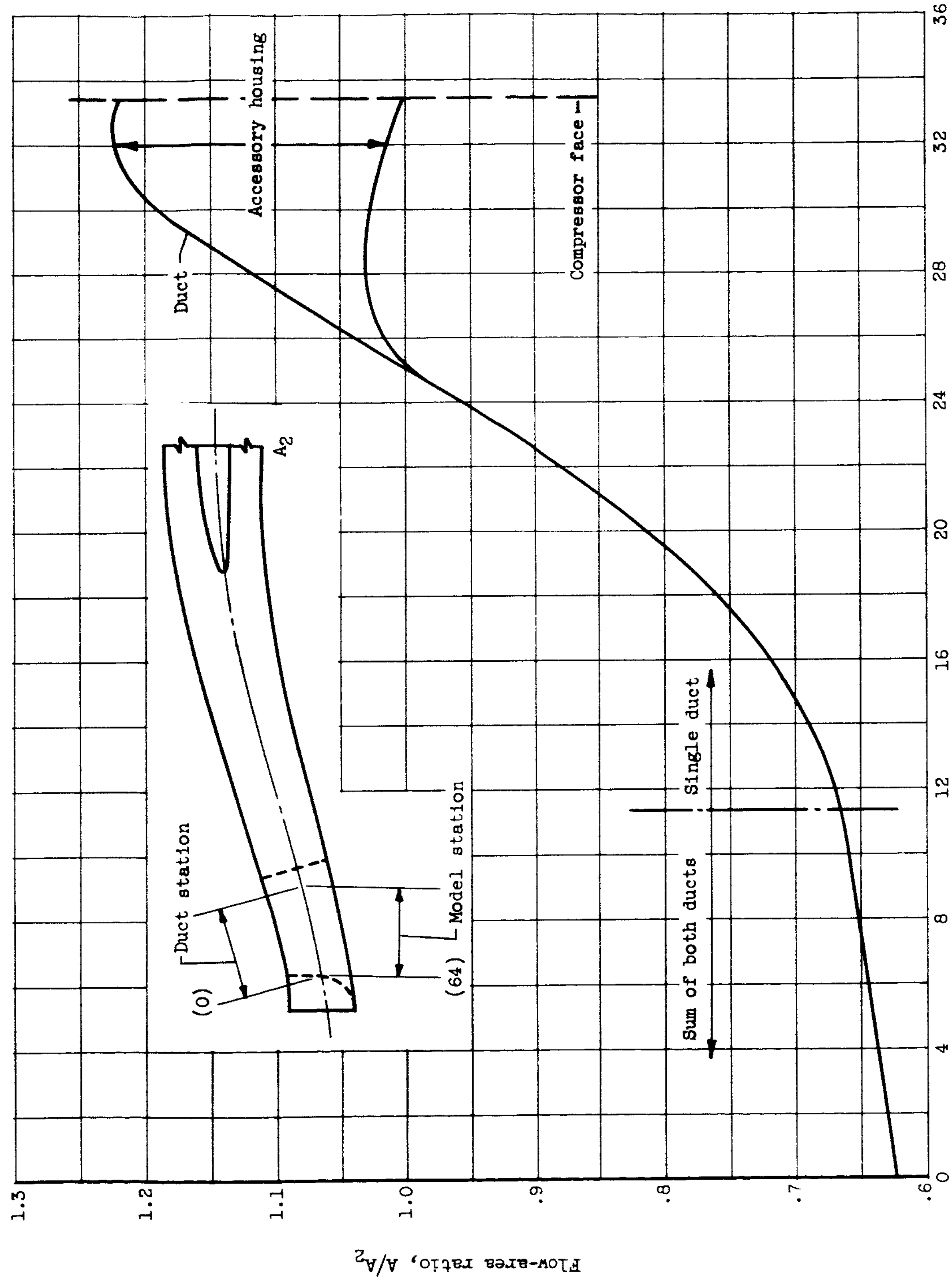

Figure 4. - Duct diffuser-area variation.

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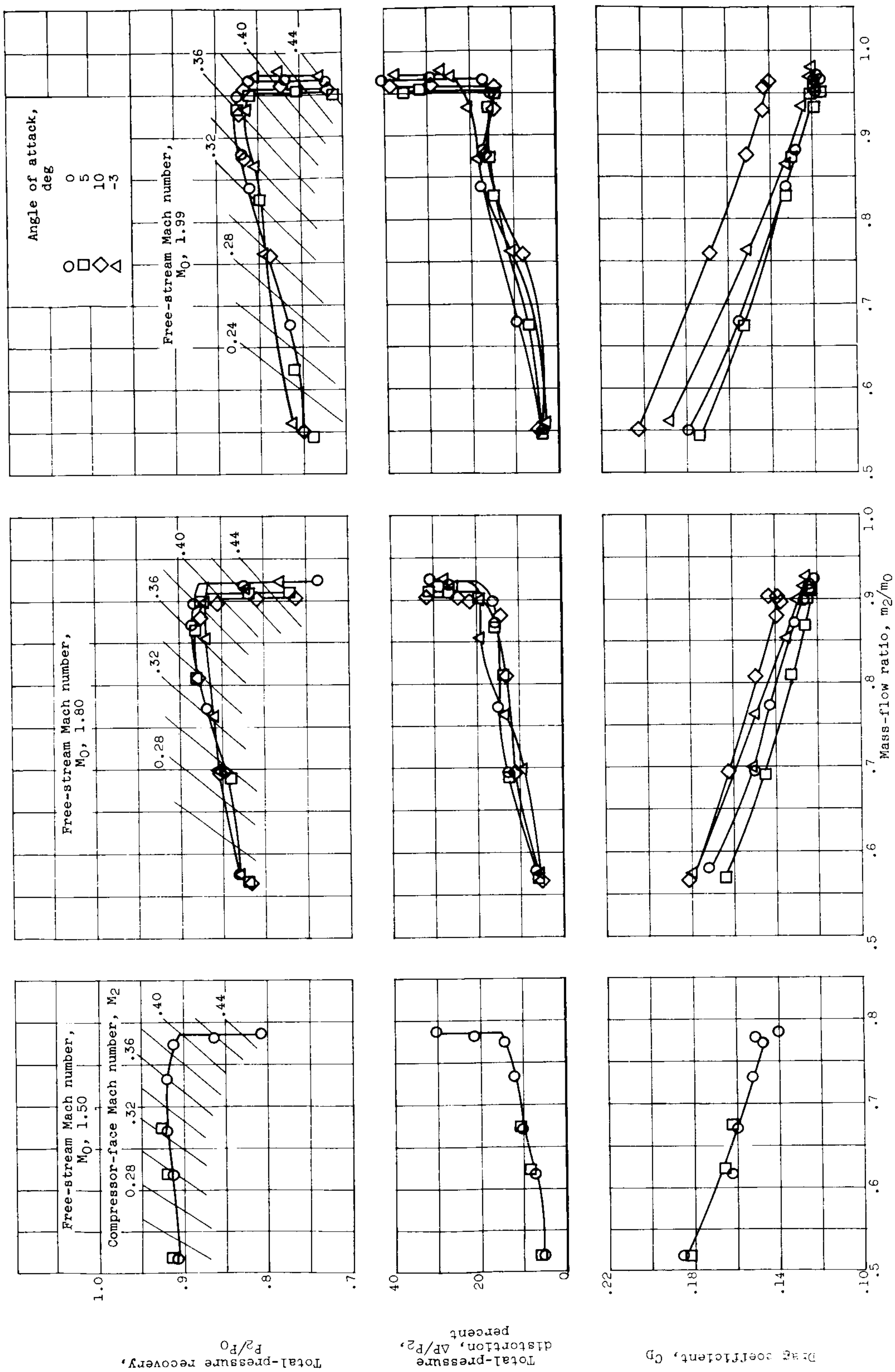

(a) Straight splitter plate.

Figure 5. - Performances of two normal-wedge configurations.

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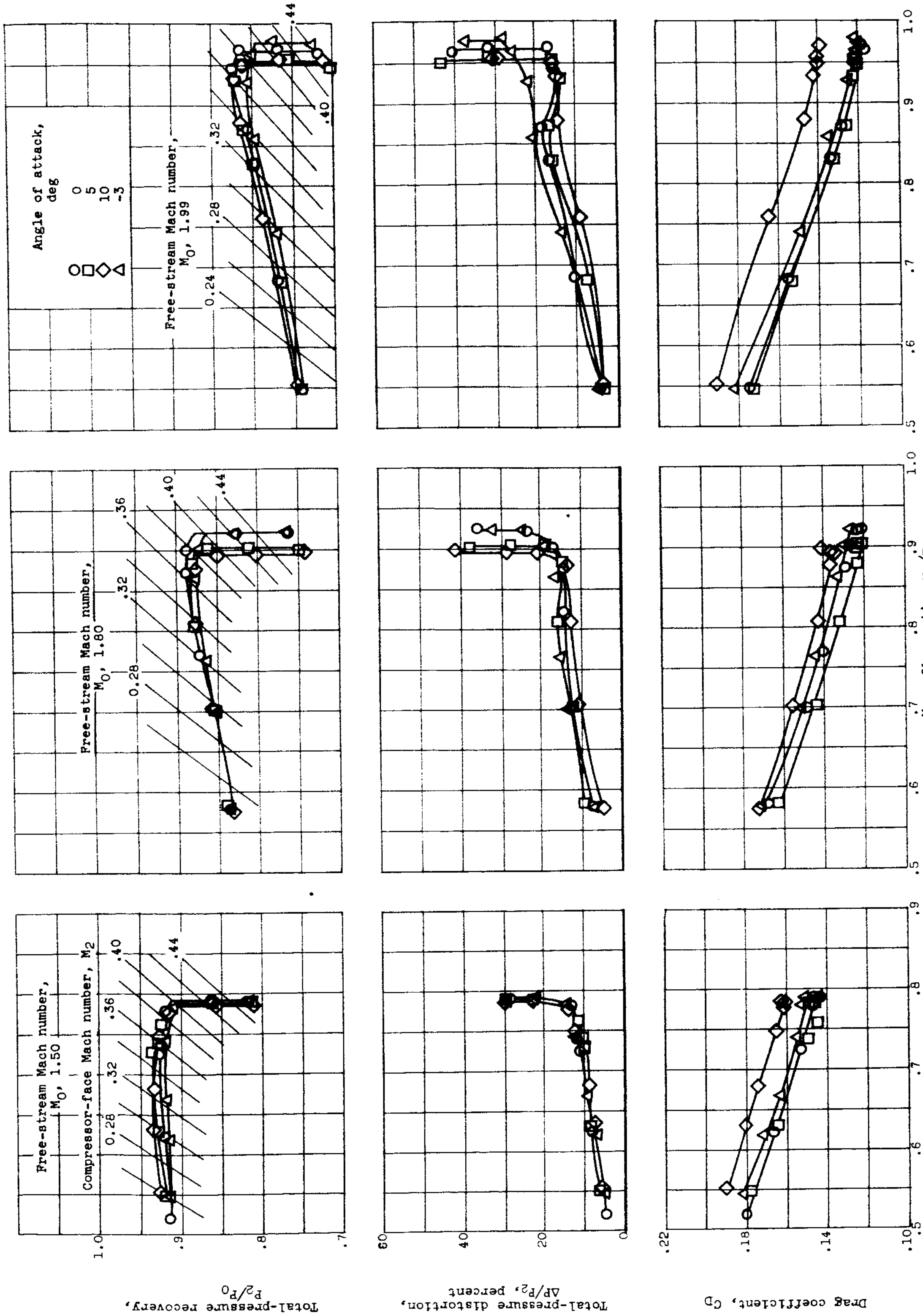

(b) Sweptback splitter plate.

Figure 5. - Concluded. Performances of two normal-wedge configurations.

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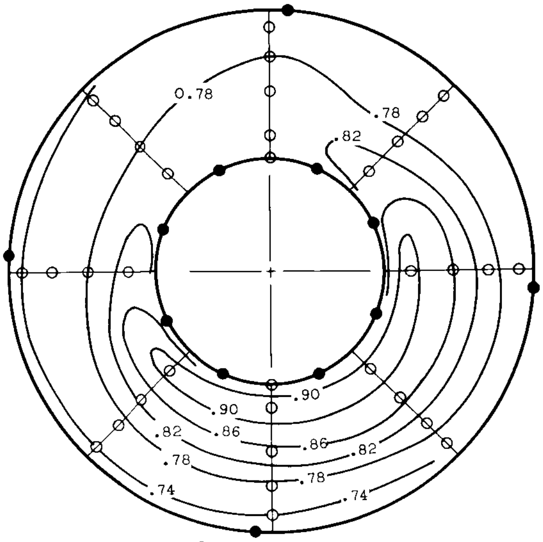
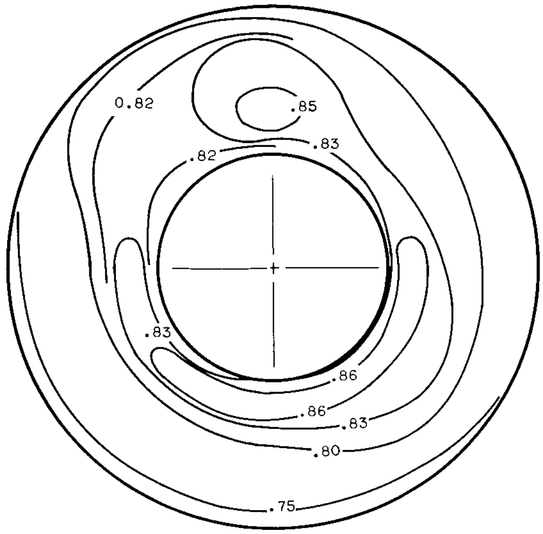
Total-pressure-ratio values

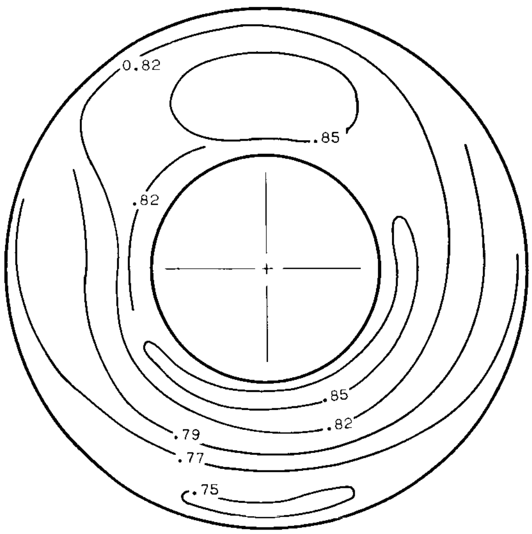


Angle of attack, -3°; mass-flow ratio, 0.972; total-pressure ratio, 0.804; total-pressure distortion, 0.236

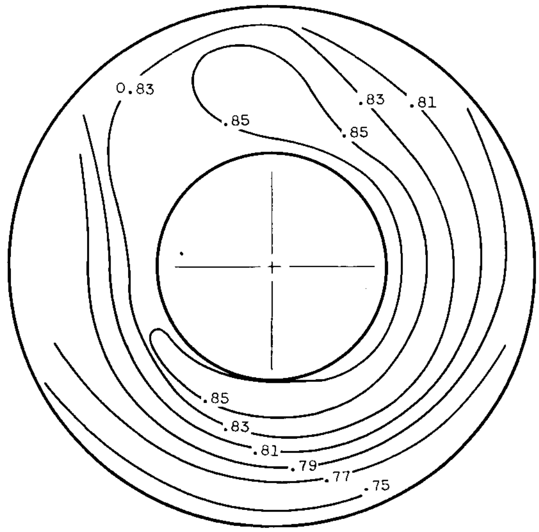
Total-pressure-ratio values



Angle of attack, 0°; mass-flow ratio, 0.967; total-pressure ratio, 0.812; total-pressure distortion, 0.173



Angle of attack, 5°; mass-flow ratio, 0.952; total-pressure ratio, 0.812; total-pressure distortion, 0.136



Angle of attack, 10°; mass-flow ratio, 0.957; total-pressure ratio, 0.816; total-pressure distortion, 0.135

(a) Effect of angle of attack. Free-stream Mach number, 1.99.

Figure 6. - Diffuser-exit total-pressure contours for straight-splitter-plate configuration.

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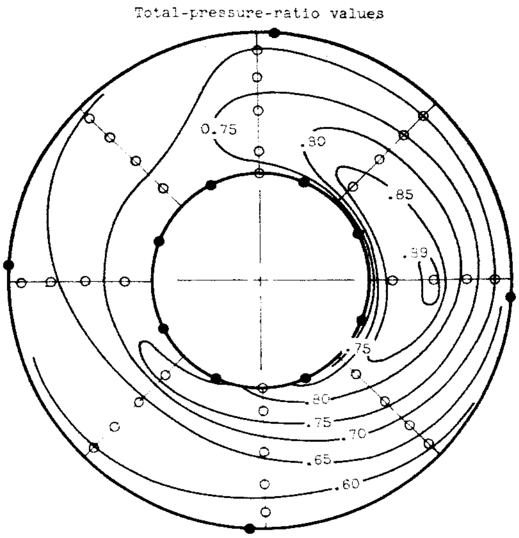
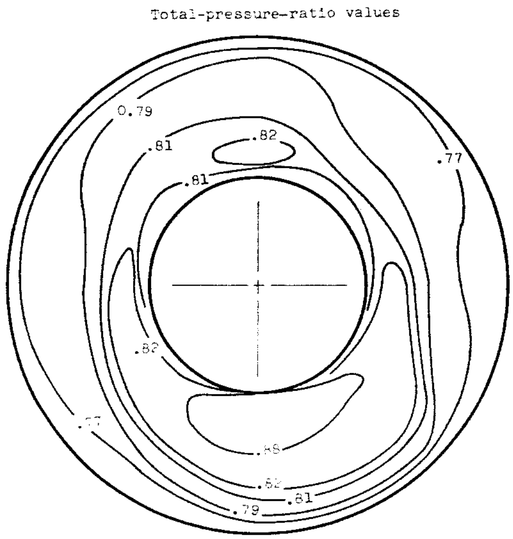
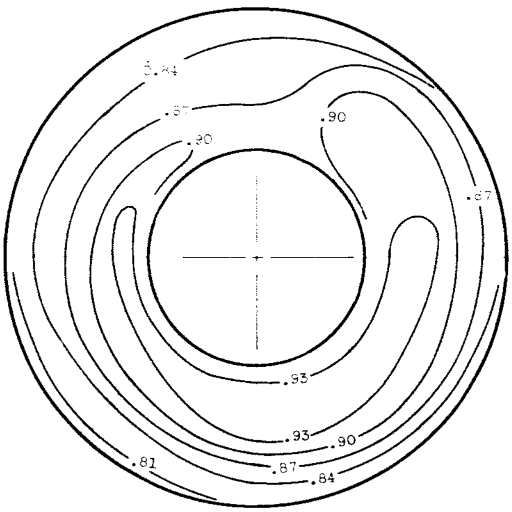


Supercritical flow; mass-flow ratio, 0.967; total-pressure ratio, 0.719; total-pressure distortion, 0.403.

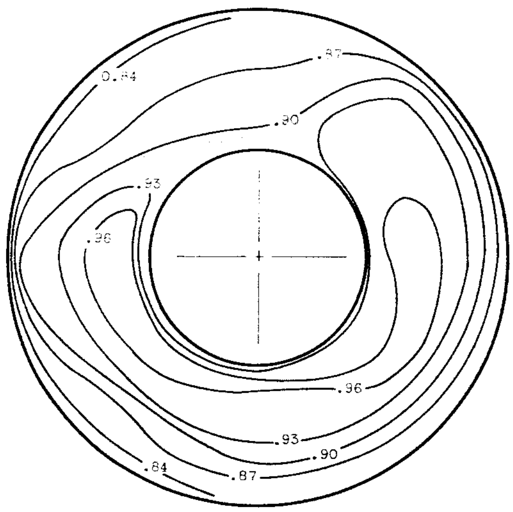


Subcritical flow; mass-flow ratio, 0.840; total-pressure ratio, 0.810; total-pressure distortion, 0.185

(b) Effect of mass-flow variation. Free-stream Mach number, 1.99.



Free-stream Mach number, 1.8; mass-flow ratio, 0.898; total-pressure ratio, 0.884; total-pressure distortion, 0.158



Free-stream Mach number, 1.5; mass-flow ratio, 0.774; total-pressure ratio, 0.910; total-pressure distortion, 0.132

(c) Effect of free-stream Mach number.

Figure 6. - Concluded. Diffuser-exit total-pressure contours for straight-splitter-plate configuration.

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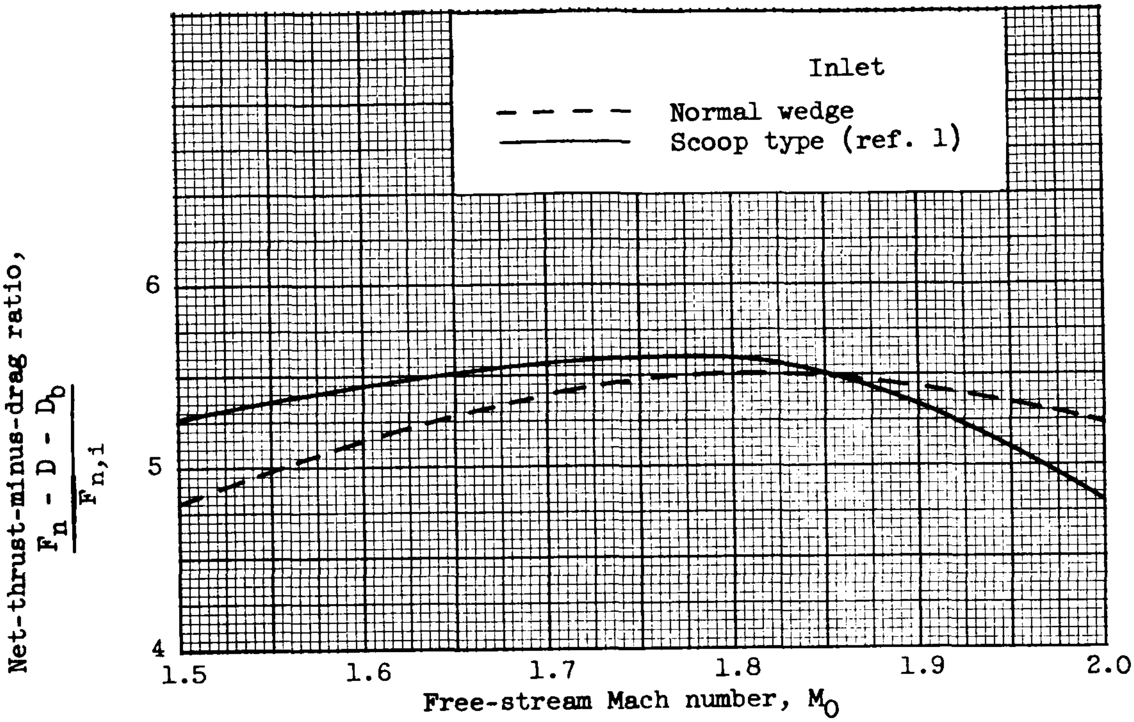

Figure 7. - Performance comparison of scoop and normal-wedge inlets at angle of attack of 5°.

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